AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

Routledge
Taylor & Francis Group

Agrekon

Agricultural Economics Research, Policy and Practice in Southern Africa

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/ragr20

Potential improvement in the performance of dairy farms in South Africa

David Beca

To cite this article: David Beca (2022) Potential improvement in the performance of dairy farms in South Africa, Agrekon, 61:4, 412-432, DOI: 10.1080/03031853.2022.2127810

To link to this article: https://doi.org/10.1080/03031853.2022.2127810

Published online: 30 Dec 2022.

Submit your article to this journal

Article views: 92

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=ragr20

AGREKON
2022, VOL. 61, NO. 4, 412–432
https://doi.org/10.1080/03031853.2022.2127810

Potential improvement in the performance of dairy farms in South Africa

David Beca

Red Sky Agricultural Pty Ltd, Melbourne, Australia

ABSTRACT
Over 2003–2021, the pasture harvested on South African pasture-based dairy farms increased markedly. This increased production and consumption of pasture has helped to reduce the cost of producing milk in South Africa relative to dairying in other countries and delivered comparatively high levels of profit. National milk production has grown steadily. Over this same time, pasture as a proportion of the total diet of dairy herds has decreased significantly: supplements make up the major share of the diet. This change to dairy herd diets puts upward pressure on the average cost of feeding the herd and on the cost of production. The focus of this paper is on whether dairy farmers would be better off if they significantly increased the proportion of pasture in the total diet of their herds and relied less on supplementary feed. It is shown that progressively increasing the pasture component and proportion in the diet of dairy herds, from an industry average of 41% to 57%, could increase profit. Results were a 26% increase in profit (return on capital), a 59% increase in profit margin per litre, and a 7% decrease in cost of production per litre. If this change in production system to increased use of pasture and less use of supplementary feeds was replicated across the entire South African pasture-based dairy industry, farmers in the industry would be significantly more profitable and their businesses would be more resilient than under the current feeding regimes that are used.

ARTICLE HISTORY
Received 22 December 2021
Accepted 18 September 2022

KEYWORDS
Dairy farming; profit; production system; pasture-based; cost of production

1. Introduction

In the 1990s, some South African farmers and their advisors[1] recognised that pasture-based dairy farmers had an opportunity to increase the pasture grown and harvested per hectare[2], reduce the cost of feed supply, and increase farm profit.

The growing dependence of dairy farmers on cows of a feedlot genotype (often United States sourced genetics) needed changing. A move to milking cows more suited to a pasture-based system (New Zealand sourced genetics) was required. A primary focus on pasture production, and a secondary focus on cow production, required a cow that was able to graze pasture intensively, maintain body condition, and get in calf.

Combining high pasture production and quantity harvested in a production system with the right type of cows, with pasture making up 55%–60% of the diet, made a relatively low-cost operation possible. The improvements in performance of businesses moving to this production system saw other farmers progressively adopting some, if not all, of the elements of a system focused on pasture as the main source of feed for dairy cows.

CONTACT David Beca david@redskyagri.com Red Sky Agricultural Pty Ltd, 3 Willowmavin Court, Kilmore, Melbourne, Victoria 3764, Australia

© 2022 Agricultural Economics Association of South Africa

Consequently, over the last two decades, there has been significant increases in the quantities of pasture harvested per hectare by dairy cows in South Africa. Compared with the major export-focused dairy producing countries of New Zealand, Australia, Argentina, Uruguay, Ireland, and United Kingdom, South Africa has made the most progress in increasing pasture harvest (Beca 2020a, 2021a). From 2003 to 2021, average pasture harvested on South African dairy farms has increased from 9 tonnes dry matter (tDM) per hectare to 12 tDM per hectare.

Over the last two decades, profit of dairy farms in South Africa, measured as percentage return on total capital managed, has also increased significantly. From 2008 to 2018, average profit increased to levels significantly above levels achieved in the export-focused dairy producing countries and United States (Beca 2020a, 2021a). From 2019, the earlier superior profit of South African dairy businesses has declined to a level with a significantly reduced margin compared to that of the main dairy producing countries.

To maintain international competitiveness, and even for the dairy industry to grow, dairy farmers in South Africa will increasingly confront the imperative to increase the productivity and profit of their business. Although profit per hectare on South African farms compares favourably to other countries, profit per cow is moderate to low compared to these countries (Beca 2020a, 2021a).

Milk production per cow in South Africa has been increasing at a relatively similar rate to other pasture-based southern hemisphere countries (Beca 2021a). The milk price received by dairy farmers in South Africa has been competitive with other southern hemisphere pasture-based countries (Beca 2020a). So, with a comparable milk price, combined with a comparatively high stocking rate per hectare, milk revenue per cow and per farm has been competitive with that of other countries, as has total revenue given milk revenue typically accounts for around 90% of total revenue.

If the comparatively low level of profit per cow in South Africa is not explained by the revenue side of the profit equation, then a poor profit per cow performance relative to dairy businesses elsewhere must be caused by costs of production being relatively higher than elsewhere. Beca (2020a, 2021a) provided evidence that South African farmers had a comparatively high cost of production in 2003–2007, albeit becoming more competitive with the costs of production achieved by dairy farmers in New Zealand, Argentina and Uruguay from 2012 onwards.

Nevertheless, milk production in South Africa has increased at an annual average rate of 3% for the last 19 years, with an annual average 3.5% increase in total solids (fat plus protein) (Beca 2020a). It is noteworthy that pasture-based farmers in South Africa have increased milk production at an annual average rate of 6%–7%, while the increase in average annual milk coming from feedlot or total mixed ration (TMR) farmers has been 1%. Pasture-based farmers, who supplied 34% of national milk supply in 1997, supplied 63% of national milk production in 2019 (MPO Lacto Data).

Pasture-based dairy farming is one of the most complex businesses to manage given the mix of ruminant livestock (cattle) and pasture/crop production, and the impact of weather and other environmental challenges, volatile prices of commodities, and a wide range of costs. The proportion of variable costs to total costs is high in dairy farming. To trade profitably, managers must continuously consider and make tactical decisions about multiple variable inputs affecting outputs of milk, livestock and pasture/crops. There is no single determining factor that dairy managers can focus on to maximise profit: there are multiple "levers" that must be "pushed" in regard to production and "pulled" in regard to cost. The best managers have mastery of the whole system.

In this paper two large dairy farm datasets are drawn on to calculate the economic impact of changes in pasture-based dairy production systems. The two datasets, one South African (Beca 2020c) and the other Australian (Beca 2020b), are unique in that every set of individual farm data encompasses a comprehensive range of financial and physical data. The physical data includes complete energy calculations in megajoules of metabolisable energy (MJ ME) which makes possible reconciled balances for milk, liveweight production, pasture and supplement intake.

2. Costs of dairying in South Africa compared with other countries

It is useful to look at costs in a dairy business in the following categories:

Variable costs

(i) Feed cost including pasture and supplements; and
(ii) "All other" variable costs including animal health, breeding, dairy shed consumables, electricity/energy, repairs and maintenance, vehicle running expenses.

Overhead costs

(iii) Labour cost including imputed costs of family and owner/operator labour and management; and
(iv) Other overheads such as depreciation, administration, rates, registrations.

In this analysis, categories (i), (ii), (iii) and (iv) are collectively termed "farm total operating costs' for analytical purposes. Deducting these variable and overhead costs from operating revenue gives operating profit and return on total capital managed. Deducting one further category of cost, which includes interest and any rental or lease costs relating to the dairy farm, leaves net profit. The focus here is on efficiency of all assets used and thus operating profit of the dairy system is the measure of performance used.

In Table 1 is shown the breakdown of feed (i), labour (iii), and all other variable and overhead costs (ii + iv) in $US cents per litre and as a percentage of total costs (i + ii + iii + iv) (Beca 2020a, 2021b).

The average split of these costs in South Africa, with the average range for pasture-based farms in brackets, are:

(i) Feed cost – 62.6% (40%–65%)
(ii) Labour cost – 11.8% (10%–25%)
(iii) "All other" variable and overhead costs – 25.6% (15%–35%).

Feed costs are the dominant cost in dairy farming. Feed costs comprise a larger percentage of total costs in South Africa than for dairy farms in the other pasture-based dairying countries. Labour costs are the next largest cost, though much lower than feed costs. Labour costs are a smaller percentage of total costs in South Africa than for the other countries. All other costs are individually much less than labour cost, and no individual cost is a large component of the "other" costs. The total of "other" variable and overhead costs comprises a similar percentage in South Africa to the average of the other countries.

Table 1. Average split of feed cost, labour cost, and "all other" costs per litre ($USc ECM) 2015–2020. Source: Red Sky, DairyBase, DFMP, QDAS, Genske Mulder, USDA, AACREA, FUCREA, Teagasc, AHDB.

2015–2020 ($US cents/litre ECM)	Total Operating Costs	Total Feed Cost	Total Labour Cost	"All Other" Costs	Feed Cost as % Total Exp.	Labour Cost as % Total Exp.	"Other" Costs as % Total Exp.
South Africa	**28.7**	**18.0**	**3.4**	**7.4**	**62.6%**	**11.8%**	**25.6%**
New Zealand	25.4	11.1	5.4	9.0	43.5%	21.3%	35.2%
Australia	34.2	18.4	7.2	8.6	53.8%	21.1%	25.1%
United States	40.3	26.4	4.9	9.0	65.5%	12.2%	22.3%
Argentina	32.3	19.8	6.4	6.0	61.5%	19.8%	18.7%
Uruguay	35.8	18.5	6.4	10.9	51.8%	17.8%	30.4%
Ireland	33.1	16.8	6.7	9.6	50.8%	20.2%	29.0%
United Kingdom*	41.5	23.2	7.2	11.1	55.9%	17.4%	26.8%
Pasture-based farms					**40%–65%**	**10%–25%**	**15%–35%**
Feedlot farms					60%–70%	10%–15%	15%–30%

All per litre costs based on energy corrected milk (corrected to 4.0% fat and 3.3% protein).
* United Kingdom data is calculated from a comparatively small dataset.

Farms in South Africa on average have the second lowest total costs per litre behind New Zealand. This is because they have low labour costs (Beca 2021c) and low non-feed costs. All costs considered, the implication follows that the feed cost of South African farms per unit of output must be comparatively high, given the comparatively low margin on a per litre and per cow basis.

Looking ahead, and with economic growth, if South Africa's labour and other costs were to increase to a similar level to the average of other southern hemisphere pasture-based dairying countries, then South African dairying would lose its advantage of low total operating costs compared to other dairying countries.

3. Why is the feed cost on South African farms comparatively high?

Two factors determine average feed cost: the cost of each of the three components of feed for dairy cows (pasture, concentrate, and non-pasture forage), and the proportion each of these components makes up in the total feed supply. Pasture cost here refers to the annual addition of inputs to the land to grow pasture. The inherent potential of the land to grow pasture is encapsulated in the price of land per hectare.

In Table 2 is outlined the average cost in $US for 2014/2015–2019/2020 of the three components of South Africa's dairy feed supply compared to the other pasture-based countries (Beca 2021b). Pasture cost in South Africa was $81 per tDM, the third lowest, and substantially higher than the pasture cost of New Zealand ($41 per tDM) and Ireland ($59 per tDM). The primary reasons why South Africa's pasture cost is much higher than these two countries, and despite pasture harvest in South Africa being much higher than in Ireland and only slightly lower than in New Zealand, is that in South Africa and unlike in Ireland or the majority of New Zealand, growing pasture relies heavily on irrigation. Further, South African dairy farmers use twice as much nitrogen fertiliser compared to their counterparts in New Zealand and Ireland. In addition, South Africa's hot temperate to subtropical climate means pasture needs to be renewed and renovated more regularly than in New Zealand and Ireland. As South African farmers are already achieving high levels of pasture harvest compared to their international peers, the scope to reduce their cost of pasture grown and consumed is limited.

Cost of concentrates in South Africa was $304 per tDM, at the mid-range of the group of countries, with Argentina having the lowest cost of concentrates at $205 per tDM and Ireland and United Kingdom having the highest cost of concentrates at around $440 per tDM. There are factors that explain some of the differences in cost of concentrates. Argentina's cost is below an open-market value because of government intervention in both the grain and milk markets. Otherwise the cost might be expected to be close to the Uruguayan cost. New Zealand relies on Palm Kernel Expeller (PKE) as a concentrate source, which is a byproduct of palm oil production and of substantially lower quality and lower price than most cereal grains. Australia, Argentina and Uruguay have access to wheat and barley, as well as maize, with wheat and barley being normally available at a

Table 2. Average cost of pasture, concentrate and non-pasture forage per tonne dry matter ($US) 2015–2020. Source: Red Sky, DairyBase, DFMP, QDAS, USDA, AACREA, FUCREA, Teagasc, AHDB.

2015–2020 ($US/tDM)	Pasture Cost *	Concentrate Cost **	Concentrate: Pasture Ratio	Forage Cost **	Forage: Pasture Ratio
South Africa	**$ 81**	**$ 304**	**+ 275%**	**$ 112**	**+ 38%**
New Zealand	$ 41	$ 251	+ 508%	$ 221	+ 436%
Australia	$ 99	$ 316	+ 219%	$ 176	+ 77%
Argentina	$ 99	$ 205	+ 108%	$ 137	+ 39%
Uruguay	$ 87	$ 249	+ 185%	$ 116	+ 33%
Ireland	$ 59	$ 433	+ 635%	$ 147	+ 150%
United Kingdom ***	$ 113	$ 446	+ 296%	$ 182	+ 61%

* Pasture cost includes fertiliser, pasture renovation, greenfeed crops and irrigation.
** Concentrate cost and forage cost include wastage and storage costs.
*** United Kingdom pasture and supplement costs are estimated.

lower cost per tonne than maize. Maize is the dominant grain in the South African market. All factors considered and given dairy farming in South Africa is not the primary end-market for maize, it seems unlikely that the cost of concentrates for dairying in South Africa could be reduced significantly.

The forage cost in South Africa was $112 per tDM, the lowest forage cost within this group of countries. South African's forage price is primarily based on maize silage, a high-quality forage. As with pasture and concentrate cost, it seems unlikely that the non-pasture forage cost of South African dairying could be reduced significantly.

Given the above argument, if the scope is limited to lower the absolute cost of the components of the total feed supply: pasture, concentrate and non-pasture forage, does opportunity exist to reduce the average cost of feed per unit of output by changing the proportions of these feed components making up total feed supply? Rebalancing the feed mix would mainly involve increasing the proportion of pasture and reducing the proportion of concentrate in the total mix. This is because the cost of concentrates in South Africa is almost four times the cost of equivalent pasture assessed on a dry matter basis. A change in the percentage of non-pasture forage is less relevant as it already has a comparatively low cost, though South African dairy farmers are apt to observe that it is difficult to source reliably their present volumes of maize silage or other alternative forages.

Over the last two decades South African farmers have substantially reduced the proportion of pasture in the cows' diet and increased the proportion of supplement, especially concentrate (Beca 2020a, 2020b). These changes are shown in Figure 1 and compared with changes in the feed mixes of six other countries. The percentage of pasture in the diet of South African cows has declined from around 55% in 2002/2003 to around 41% in 2020/2021.

The impact of variations in the percentage of pasture in the diet of the cow (holding output constant) is demonstrated in Table 3 for South Africa. The same impact was reported by Beca (2021b) in relation to Australian feed costs. The results of the two calculations are shown in the table: one where the pasture cost is held constant for all options of pasture proportion in the diet, and the second where pasture cost is lower when pasture is a higher proportion of the diet. The variations in pasture cost for differing proportions of pasture in the diet are based on an analysis of a large unbiased Australian dataset detailed by Beca (2020b).

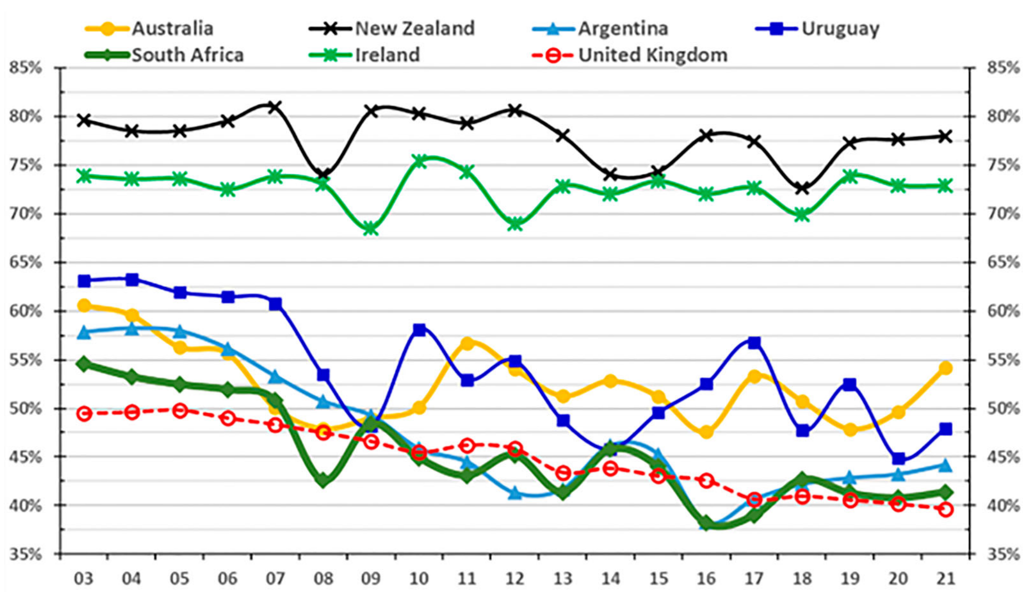

Figure 1. Percentage of pasture in the cows' diet 2003–2021. Source: DFMP, QDAS, Red Sky, DairyBase, AACREA, FUCREA, Teagasc, AHDB.

Table 3. Change in consumed feed cost in $US per tDM as percentage of pasture in the cows' diet changes (2015–2020).

Pasture per cent of diet	0%	20%	30%	40%	50%	60%	70%	80%
Pasture cost *		$81	$81	$81	$81	$81	$81	$81
Pasture cost **		**$97**	**$89**	**$82**	**$74**	**$66**	**$59**	**$51**
Concentrate cost ***	$304	$304	$304	$304	$304	$304	$304	$304
Forage cost ***	$112	$112	$112	$112	$112	$112	$112	$112
Supplement cost ****	$227	$246	$246	$246	$246	$246	$246	$246
Average feed cost *	$227	$213	$197	$180	$164	$147	$131	$114
Average feed cost **	**$227**	**$217**	**$199**	**$181**	**$160**	**$138**	**$115**	**$90**

* Pasture cost (and Average feed cost) include pasture cost held constant for all variations in pasture per cent.
** Pasture cost (and Average feed cost) include pasture cost adjusted for impact of variations in pasture per cent.
*** Concentrate cost and forage cost include wastage and storage costs.
**** Supplement cost based on 70% concentrate plus 30% forage, except for 0% pasture which is split 60:40.

The calculation of average feed cost for the two diets containing different proportions of pasture highlight the large negative impact on the total feed cost of more concentrate and less pasture. Moving from 70% pasture in the diet to 30% pasture in the diet for the average South African farmer increases the average cost of feed per cow by around 50-75%, or from $115 to $199 per tonne dry matter. This changed mix of feedstuffs increases average feed cost per litre, which with output maintained would decrease operating profit and percentage return on capital.

There is supporting evidence that increased pasture as a percentage of the cows' diet is related positively with farm profit. Macdonald and others (2017) reported a decline in operating profit per hectare when stocking rate was increased to the extent that a substantial increase in imported supplement was required. Ramsbottom and others (2015) reported that there was a decline in profit per hectare, per cow, and per litre associated with increasing milk production per cow and per hectare through the supply of additional imported supplement. In both the above-mentioned cases, although the impact on profit as defined by return on capital was not reported, the increased use of supplementary feed would have a greater decline in return on capital than profit per hectare because of the additional capital invested in cows and machinery. Pasture harvested per hectare also declined as the amount of supplement fed per cow increased (Macdonald et al. 2017; Beca 2020b, 2020c).

In addition, studies by Hanson et al. (1998) and Kriegl (2001) found that pasture-based dairy systems were more profitable than feedlot (confinement) systems, including in the United States, reporting that profit decreases as the percentage of supplement in the cows' diet increases. Dillon et al. (2005) found that farms in countries that had a higher percentage of pasture in the diet had a significantly lower cost of production. Chapman et al. (2014) identified an increase in business risk through increased exposure to supplement cost with higher stocking rates and a higher reliance on supplement, including when this supplement was comparatively low-cost home-grown crops other than pasture.

Although it is evident that an increase in the percentage of pasture in the cows' diet for an average South African dairy farm, and for the dairy industry in total, should result in a reduction in cost of production per litre, an increase in profit margin per litre, an increase in profit per cow, and an increase in whole farm profit as represented by return on capital, this has historically been difficult to quantify. A change in the percentage of pasture in the diet has a large number of impacts on both animal and pasture production, reverberating through a range of the cost centres (Beca 2020b). In the following, the overall impacts are estimated by analysing whole farm performance of actual dairy farm businesses in South Africa and Australia. The identified effects at whole farm level are included in a model of an average South African pasture-based dairy farm, and the impact of increasing pasture share of total feed supply on a range of farm performance ratios is calculated.

4. Method

Two sources of data about performance of dairy farms, one from Australia and the other from South Africa, are analysed to determine the impact of changes in the percentage of pasture in the cows' diet on animal and pasture production, as well as on all relevant cost centres. The Australian dataset included 207 sets of dairy farm data from 2005/2006 which were primarily from the four more southerly states of Victoria, Tasmania, South Australia and Western Australia. A fuller description of this dataset is reported in Beca (2020b).

The South African dataset included 244 sets of dairy farm data from the four years of 2014/2015, 2015/2016, 2016/2017 and 2017/2018. The farms are primarily from two provinces; KwaZulu-Natal and Eastern Cape, although there are a small number of datasets from outside these provinces. A fuller description of this dataset is reported in Beca (2020c).

All the sets of farm data were processed through Red Sky software, so they have been analysed using a uniform method. In Table A1 in the Appendix the method for calculating operating profit is set out, which is the same as described by Beca (2020a, 2020b) and similar to that described by Hemme, Uddin, and Ndambi (2014). Financing and lease/rent costs were excluded from calculation of operating profit, other than where a lease/rent cost pertains to a support area utilised for livestock production (e.g., heifer growth) or feed production and, as a result, was included as a variable cost of feed supply. Growth of the value of assets is treated as a separate form of income and is excluded from the calculation of operating profit.

In Table A2 in the Appendix is the method used for calculating each of the ratios used in this paper. The software program, R (R Core Team 2013), was used for the statistical analysis.

To determine the impact of an increase in the percentage of pasture in the cows' diet, a base year was developed against which the effects of changes in percentage of pasture could be assessed. This base year is the equivalent of the business performance of an average South African farm in 2019/2020. Red Sky benchmark performance in 2019/2020 for South Africa pasture-based dairy farms was used as a base.

The base year is a steady-state model, developed using Red Sky software, where land area, livestock numbers by category, and all other assets are maintained at the same number and value per unit at the start and end of the year. This results in nil net capital appreciation or capital depreciation of assets. The following assumptions were used:

(i) Land and building values are based on 2019/2020 values, which were R135 000 per hectare for dairy land and R37 000 per hectare for support land. The dairy land is 80% irrigated and 20% dryland (non-irrigated), with the value of irrigated land being R153 000 per hectare and the value of dryland being R63 000 per hectare. The support land was entirely dryland.
(ii) Milk price is based on the average of 2015/2016–2019/2020 values, which was R4.60 per litre for milk composition of 3.89% fat and 3.36% protein calculated on a mass divided by mass basis (4.00% fat and 3.45% protein calculated on a mass divided by volume basis).
(iii) Livestock values are based on the average of 2017/2018–2019/2020 values, which included R12 000 per head for cows, R11 500 per head for 13–24 month heifers, and R4 000 per head for 1–12 month heifers.
(iv) Concentrate price is based on the average of 2015/2016–2019/2020 values, which was R3 800 per tonne.
(v) All other commodity prices, including maize silage, other silages, hay, nitrogen, and other fertilisers, are based on the average of 2015/2016–2019/2020 values.
(vi) Pasture harvest is based on an average of 2016/2017–2019/2020 values, which was 12.6 tonnes of dry matter per hectare for irrigated land and 6.3 tonnes of dry matter per hectare for dryland, resulting in an average pasture harvest across the 80% irrigated land and 20% dryland of 11.34 tonnes of dry matter per hectare.
(vii) All other costs are based on an average of 2018/2019–2019/2020 values.

When calculating the average values outlined above, adjustments were made to reduce the impact of individual year values that appeared anomalous.

Values for land and buildings, livestock, and vehicles and machinery were provided predominantly by farm business owners in conjunction with a dairy farm consultant that had experience in the region where the farm was located. Comparisons of values across farms within a region, and between regions, were also done to ensure a high level of consistency with these asset values.

This base year has pasture contributing 41% of the cows' diet, concentrate contributing 37% of the diet, and non-pasture forage contributing the remaining 22%. All percentages of feeds in the total feed mix are calculated on the basis of megajoules of metabolisable energy contributed by each feed group.

Four further models were used, each with 4% increments of pasture percentage, which resulted in these models including 45%, 49%, 53% and 57% pasture in the cows' total diet.

To calculate the key variable inputs for the models, regression analysis was done for the ratios outlined in Table 4. Relationships printed in italics are not significant as the *P* value is greater than 0.05. However, some relationships do have a *P* value only slightly higher than 0.05.

Several cost centres have been assessed as being unaffected by changes in the percentage of pasture in diet. These are the costs that can be assessed as a mix of per-hectare and fixed costs, with these being fertiliser, irrigation, pasture maintenance and renovation, greenfeed cropping (grazed in situ), administration expenses including professional fees, and overheads including rates and insurance.

In Table 5 it is shown how the Australian and South African data in Table 4 has been converted into a percentage change in each ratio for each 1% change in pasture in the diet. This table includes the x-multiple from each linear regression and the median value from the data. From these, a percentage change in each ratio for each 1% increase in the percentage of pasture in the diet is calculated, as well as an average of the Australian and South African values.

The final (far right) column in Table 5 contains the values used in the models. These values differ to the average in most instances, with the difference due to a number of factors. First, the Australian data has less bias and so often received more weighting. Second, some relationships are categorised as not significant, which influenced the weighting. Third, arguments in causation have been employed in two instances, relating to grazing and support area per cow, and depreciation per cow.

Grazing and support area costs are unchanged in absolute terms in all models. Most farmers own or lease support land. The assumption was that any reduction in livestock numbers and demand for feed would not be matched by a reduction in support area costs. As the percentage of pasture in the diet increases, there is an associated reduction in the non-pasture forage cost due to a greater surplus of forage being produced, which is a result of fewer animals being farmed.

The models include a reduction in depreciation as the percentage of pasture in the diet increases, rather than the increase evident in the data. This change has been implemented as most depreciating assets are utilised less as the pasture percentage increases due to cows

Table 4. Results from analysis of datasets for input into models.

Pasture percentage in cows' diet impact on ratio listed	AUSTRALIA			SOUTH AFRICA		
	R^2	*P*	Equation ($AU)	R^2	*P*	Equation (ZAR)
Pasture harvest (tDM/ha)	0.100	<= 0.001	y = 4.07 + 6.33 x	0.300	<= 0.001	y = 3.17 + 17.2 x
Milk production per cow	0.320	<= 0.001	y = 9360 − 4770 x	*0.005*	*0.274*	*y = 6070 − 662 x*
Animal health per cow	0.120	<= 0.001	y = 86.6 − 57.6 x	0.064	<= 0.001	y = 1240 − 872 x
Breeding & herd testing per cow	0.094	<= 0.001	y = 75 − 50.4 x	0.032	0.00548	y = 488 − 276 x
Dairy shed expenses per cow	0.028	0.0159	y = 32.3 − 11.1 x	*0.011*	*0.0978*	*y = 295 − 118 x*
Electricity per cow	0.061	<= 0.001	y = 42.1 − 17.8 x	0.032	0.00519	y = 547 − 282 x
Grazing & support area per cow	0.050	0.00117	y = 197 − 126 x	*0.00039*	*0.759*	*y = 800 + 81.6 x*
Freight per cow	*0.00074*	*0.697*	*y = 8.52 − 1.36 x*	*7.30E-08*	*0.997*	*y = 10.5 − 0.0573 x*
Repairs & maintenance per cow	0.021	0.0389	y = 109 − 32.8 x	*0.0011*	*0.613*	*y = 950 − 109 x*
Vehicle expenses per cow	0.021	0.0363	y = 72.2 − 23.3 x	0.034	0.00375	y = 1500 − 646 x
Labour cost (total) per cow	0.079	<= 0.001	y = 582 − 216 x	0.025	0.0137	y = 3100 − 1040 x
Wages & employment exp. per cow	0.094	<= 0.001	y = 358 − 278 x	0.020	0.0273	y = 2710 − 910 x
Depreciation per cow	0.029	0.015	y = 92.9 + 60.4 x	*0.013*	*0.0745*	*y = 985 + 326 x*

Numbers in *italics* confirm relationships that are not considered significant as *P* value greater than 0.05.

Table 5. Calculation of percentage change for input into models.

Pasture percentage in cows' diet impact on ratio listed	AUSTRALIA (AUS)		SOUTH AFRICA (SA)		AUS 1% change	SA 1% change	Average 1% change	Modelled 1% change
	x-multiple	Median*	x-multiple	Median*				
Pasture harvest (tDM/ha)	+ 6.3	7.78	+ 17.2	10.69	+ 0.81%	+ 1.61%	+ 1.21%	+ 0.99%
Milk production per cow (litres)	−4 770	6 514	*−662*	*5 917*	−0.73%	*−0.11%*	−0.42%	−0.48%
Animal health per cow	−57.6	50	−872	824	−1.15%	−1.06%	−1.11%	−1.09%
Breeding & herd testing per cow	−50.4	40	−276	335	−1.26%	−0.82%	−1.04%	−1.06%
Dairy shed expenses per cow	−11.1	25	*−118*	*242*	−0.44%	*−0.49%*	−0.47%	−0.47%
Electricity per cow	−17.8	30	−282	401	−0.59%	−0.70%	−0.65%	−0.46%
Grazing & support area per cow	−126	104	*+ 81.6*	*733*	−1.21%	*+ 0.11%*	−0.55%	+ 1.00%
Freight per cow	*−1.36*	*6*	*−0.0573*	*0*	*−0.23%*	n/a	n/a	n/a
Repairs & maintenance per cow	−32.8	83	*−109*	*845*	−0.40%	*−0.13%*	−0.26%	−0.49%
Vehicle expenses per cow	−23.3	57	−646	1 205	−0.41%	−0.54%	−0.47%	−0.61%
Labour cost (total) per cow	−216	365	−1 040	2 605	−0.59%	−0.40%	−0.50%	−0.42%
Wages & employment exp. per cow	−278	181	−910	2 305	−1.54%	−0.39%	−0.97%	−0.40%
Depreciation per cow	+ 60.4	122	*+ 326*	*1 116*	+ 0.50%	*+ 0.29%*	+ 0.39%	−0.75%

Numbers in *italics* confirm relationships that are not considered significant as P value greater than 0.05
* median value for dataset

being fed less supplement, and less crops being grown and conserved, as well as cows producing less milk which would result in reduced water requirements and shorter milking times. The probable reason for this not being expressed in the data is that depreciation is often reported based on standard rates from national accounting standards rather than on real "life-of-asset" or utilisation rates.

Freight, which relates to livestock freight only, does not have a value associated with it. Firstly, there was not a significant association in either dataset, and secondly, most farms include livestock freight within net livestock revenue under income. This is confirmed in the South African data by the median value for freight per cow being R0 and the average value being R10. As a result, the base year includes all livestock freight being included within net livestock revenue, with freight per cow being nil.

Although a considerable amount of data analysis, along with further consideration of causal relationships, were employed to set the assumptions utilised in the models, these should be assessed as representing an estimate of a probable outcome. As noted in the discussion, one recommendation is that further research be undertaken to identify with more confidence the impact of changes to the percentage of pasture in the cows' diet on dairy farm performance.

In Table 6 is shown the results of the assumed changes per 1% of pasture in the cows' diet on the four models in comparison to the base year. This table includes the progressive reduction in the percentage of concentrate and non-pasture forage that occurs as a result of the increase in pasture percentage. In addition to these percentage changes in feed mix, there is also the amount of each of these feed components consumed per cow per year and the total amount of feed consumed per cow, as well as the approximate amount of concentrate consumed per cow per day.

Milk production per cow decreases from 6 100 litres with 41% of pasture in the diet to 5 636 litres with pasture at 57% of total diet, a reduction of 7.6% in milk output. The annual total dry matter intake per cow for this case decreases from 5.52 tDM to 5.31 tDM (−3.8%). The pasture dry matter intake per cow increases from 2.37 tDM to 3.13 tDM (+32.1%), whereas the concentrate dry matter intake per cow decreases from 5.87 tDM to 4.07 tDM (−30.7%), and the non-pasture forage dry matter intake per cow decreases from 1.36 tDM to 0.94 tDM (−30.9%). These changes are determined by the comprehensive energetic calculation based on megajoules of metabolisable energy in the Red Sky software, which ensures milk and liveweight production is reconciled with pasture and supplement intake. The models are utilising the same energy content for pasture,

Table 6. Input production parameters to models.

South Africa Production System Parameters	Change per +1% Pasture	Base Year 41% Pasture	Model #1 45% Pasture	Model #2 49% Pasture	Model #3 53% Pasture	Model #4 57% Pasture
Pasture as % of cow diet [1]	**+ 1.0%**	**41.0%**	**45.0%**	**49.0%**	**53.0%**	**57.0%**
Concentrate as % of cow diet [1]	−0.63%	37.0%	34.5%	32.0%	29.5%	27.0%
Forage as % of cow diet [1]	−0.38%	22.0%	20.5%	19.0%	17.5%	16.0%
Pasture per cow (tDM/year) [2]	**+ 0.048**	**2.37**	**2.56**	**2.76**	**2.94**	**3.13**
Concentrate per cow (tDM/year) [3]	**−0.034**	**1.79**	**1.66**	**1.51**	**1.38**	**1.24**
Concentrate per cow (kgDM/day est.) [3]	−0.113	5.87	5.43	4.96	4.51	4.07
Forage per cow (tDM/year) [4]	−0.026	1.36	1.25	1.15	1.05	0.94
Total consumed per cow (tDM/year) [2,3,4]	−0.013	5.52	5.47	5.42	5.37	5.31
Pasture harvest (tDM/ha) [2]	**+ 0.1125**	**11.34**	**11.79**	**12.23**	**12.69**	**13.12**
Production per cow (litres)	**−29.0**	**6 100**	**5 984**	**5 868**	**5 752**	**5 636**
Cow liveweight (kg)	−0.50	560	558	556	554	552
Price of concentrate (Rand/tonne)	-R 5.00	R 3 800	R 3 780	R 3 760	R 3 740	R 3 720
Animal health per cow	-R 11.37	R 1 040	R 995	R 949	R 904	R 858
Breeding per cow	-R 4.88	R 460	R 440	R 421	R 401	R 382
Dairy shed expenses per cow	-R 1.23	R 265	R 260	R 255	R 250	R 245
Electricity per cow	-R 2.42	R 530	R 520	R 511	R 501	R 491
Grazing/support area per cow	+R 9.50	R 950	R 988	R 1 022	R 1 050	R 1 077
Freight per cow	n/a	R 0	R 0	R 0	R 0	R 0
Repairs & maintenance per cow	-R 5.14	R 1 050	R 1 029	R 1 009	R 988	R 968
Vehicle expenses per cow	-R 8.21	R 1 350	R 1 317	R 1 284	R 1 252	R 1 219
Management & labour expenses per cow	-R 14.67	R 3 465	R 3 406	R 3 345	R 3 281	R 3 217
Labour/staff expenses per cow	-R 11.17	R 2 800	R 2 755	R 2 711	R 2 666	R 2 621
Imputed management per cow	-R 3.50	R 665	R 651	R 634	R 615	R 596
Depreciation per cow	-R 9.90	R 1 320	R 1 280	R 1 241	R 1 201	R 1 162

1 = percentage calculated on basis of MJ ME.
2 = pasture standardised to 10.5 MJ ME per kgDM.
3 = concentrate standardised to 12.5 MJ ME per kgDM.
4 = forage standardised to 9.5 MJ ME per kgDM.

concentrate and non-pasture forage that was collected and incorporated in the individual sets of farm data.

Although there is an argument that the cow response to the change in diets may be different to that modelled, these responses are supported by the regression analysis of the two datasets. Approximately 89% of the pasture component in the diet is from the 80% of the modelled farm that is irrigated, with a significant proportion of the balance of the pasture coming from comparatively good quality spring dryland (non-irrigated) pasture. This pasture will be higher in energy content on average, and significantly higher in protein content, than the non-pasture forages. Although the pasture will be lower in energy content than concentrates, and higher in fibre which will reduce intake, it will on average be higher in protein content than concentrates. There is also an argument that there may be a higher pasture quality (i.e., higher energy density and lower fibre) associated with the higher pasture harvest that is an outcome of the higher pasture percentage in the diet, which may be contributing to the changes in milk production and dry matter intake that are evident in the two datasets.

Cow liveweight is also included in Table 6 with 560 kilograms being the base year value. This is reduced by 0.5 kg per cow per 1% increase in pasture in the diet, which equates to a reduction of 2 kilograms per cow per model. This is included as partial recognition of the likely change in cow size due to a change in cow genotype associated with breeding a cow that is more adapted to consuming a higher percentage of pasture and a lower percentage of concentrate. This change in cow genotype was described by Harris and Kolver (2001).

The price of concentrate is also included in Table 6. This is reduced by R5 per tonne per 1% increase in pasture in the diet, which equates to a reduction of R20 per tonne per model. This reduction in price of concentrate is included for three reasons. First, with increasing pasture percentage in the diet, primarily irrigated pasture, and decreasing concentrate and non-pasture forage percentage, the protein content of the diet will increase because of the much higher protein content of pasture compared to cereal grains and maize silage. As a result, the protein in the concentrate could be reduced. Second, these same factors would result in the mineral and trace element content of the diet increasing because of the higher level of most minerals and trace elements in pasture compared to cereal grains and maize silage. This may have little, if any, net impact on concentrate price, due to it being offset by the need to include the supplemented minerals and trace elements in a lower daily intake of concentrate per cow. Third, the protein, mineral and trace element requirements per cow will be lower due to the progressive reductions in the level of milk production per cow as pasture percentage in the diet increases.

Imputed management cost is also included in Table 6. This is calculated from the difference between total management and labour expenses per cow and direct payments for labour/staff expenses per cow.

The final two inclusions in the calculation of operating profit are net livestock revenue and other non-milk revenue. Livestock revenue per cow is unchanged in all models. This is because pregnancy and birth rates remain unchanged in all models when calculated on the basis of the percentage of cows in herd. Similarly, heifer replacement rates are unchanged in all models. Other non-milk and non-livestock revenue is unchanged in absolute value terms in all models. This is based on the assumption that this small source of revenue (0.3% of total revenue) would be unchanged due to it not being related to milk or livestock production.

5. Results

In Table 7 the changes in production parameters utilised in the models are summarised, with the right-hand column outlining the percentage difference between the model with 57% pasture in the cows' diet and the base year. The most noteworthy differences between the 57% model and the base year are that stocking rate on the pasture area has decreased by 11.9%, pasture harvest has increased by 15.7%, milk production per cow has decreased by 7.6%, and milk production per hectare has decreased by 18.5%.

Table 7. Production parameters included in models.

South Africa Production System Parameters	Base Year 41% Pasture	Model #1 45% Pasture	Model #2 49% Pasture	Model #3 53% Pasture	Model #4 57% Pasture	Difference 57% to 41%
Size of dairy farm (effective hectares)	134.0	134.0	134.0	134.0	134.0	+ 0.0%
Size of support farm (effective hectares)	208.0	208.0	208.0	208.0	208.0	+ 0.0%
Number of cows in herd	603	580	561	546	532	−11.8%
Stocking rate on effective area	4.50	4.33	4.19	4.07	3.97	−11.8%
Stocking rate on pasture area	**4.63**	**4.45**	**4.30**	**4.19**	**4.08**	**−11.9%**
Stocking rate on irrigation*	5.14	4.94	4.78	4.66	4.53	−11.9%
Stocking rate on dryland*	2.57	2.47	2.39	2.33	2.27	−11.9%
Pasture harvest (tDM/ha)	**11.34**	**11.79**	**12.23**	**12.69**	**13.12**	**+ 15.7%**
Irrigated* pasture harvest (tDM/ha)	12.60	13.10	13.59	14.10	14.58	+ 15.7%
Dryland* pasture harvest (tDM/ha)	6.30	6.55	6.79	7.05	7.29	+ 15.7%
Production per cow (litres)	**6 100**	**5 984**	**5 868**	**5 752**	**5 636**	**−7.6%**
Production per hectare (litres)	**27 450**	**25 901**	**24 567**	**23 437**	**22 376**	**−18.5%**
Milk solids %	7.25%	7.25%	7.25%	7.25%	7.25%	+ 0.0%
Fat %	3.89%	3.89%	3.89%	3.89%	3.89%	+ 0.0%
Protein %	3.36%	3.36%	3.36%	3.36%	3.36%	+ 0.0%

* model farm includes 80% irrigated land and 20% dryland.

Milk fat and protein percentages are unchanged in the models, although the change in diet composition would have some impact in increasing these components, especially the fat percentage given the increase in dietary fibre levels. Any change in cow genotype could also have an impact on these milk component percentages. A change in milk components would not have any impact on the results from the modelling, with the possible exception of milk price, as Red Sky software includes energetic calculations that account for the specific energy required to produce fat and protein. However, if a change in milk components per litre was not compensated through a change in milk price per litre, then this would impact on the reported financial results.

In Table 8 are the changes in output results in the models, with the right-hand column again outlining the percentage difference between the model with 57% pasture in the cows' diet and the base year. The most noteworthy physical output differences between the 57% model and the base year are that the pasture per cent in the cows' diet increases by 39%, concentrate per cent decreases by 27%, and non-pasture forage decreases by 27.3%.

The 27% reduction in concentrate in energy terms equates to a 30.7% decrease in the quantity of concentrate fed per day and per year. The 27.3% reduction in non-pasture forage in energy terms equates to a 40.3% decrease in both the volume of maize silage required annually and the area of maize silage sown and harvested.

The most noteworthy changes in financial performance between the 57% model and the base year are that profit as defined by return on capital increases by 26.3% (+1.58%), absolute operating profit increases by 29.5% (+R544 610 or +$US36 307), profit per hectare increases by 29.4% (+R4 064 or +$US271), profit per cow increases by 46.7% (+R1 433 or +$US96), profit margin per litre increases by 58.8% (+R0.30 or +$US0.02), and cost of production per litre decreases by 7.2% (-R0.30 or -$US0.02). The conversion to US dollars was at an exchange rate of 15.0 Rand to the United States dollar.

The improvements in financial performance are substantial. The largest gains are in farm operating profit, and the associated profit per cow and profit margin per litre. The increase in profit per cow addresses the potential present area of weakness in the South African dairy industry's business performance. The increase in profit margin per litre would place the dairy industry, and the farmers within the industry, in a position of greater business resilience that would ensure volatility in milk price, other commodity prices, climate, or other factors could be more readily accommodated.

An important question in relation to these results is how sensitive are they to the most significant factors that affect business performance. This question is addressed in the next section.

Table 8. Output results from models.

South Africa Production System Parameters	Base Year 41% Pasture	Model #1 45% Pasture	Model #2 49% Pasture	Model #3 53% Pasture	Model #4 57% Pasture	Difference 57% to 41%
Pasture as % of cow diet	**41.0%**	**45.0%**	**49.0%**	**53.0%**	**57.0%**	**+ 39.0%**
Concentrate as % of cow diet	37.0%	34.5%	32.0%	29.5%	27.0%	−27.0%
Forage as % of cow diet	22.0%	20.5%	19.0%	17.5%	16.0%	−27.3%
Concentrate per cow (tonne/year)	1.99	1.84	1.68	1.53	1.38	−30.7%
Concentrate per cow (kg/day est.)	6.52	6.03	5.51	5.02	4.52	−30.7%
Maize silage required per year (tDM)	884	780	689	606	528	−40.3%
– Hectares maize silage required (ha)	58.9	52.0	45.9	40.4	35.2	−40.3%
Milk price per litre	R 4.60	R 4.60	R 4.60	R 4.60	R 4.60	+ 0.0%
Return on capital	**6.01%**	**6.41%**	**6.82%**	**7.23%**	**7.59%**	**+ 26.3%**
Profit (total operating)	R 1849 145	R 1986 441	R 2127 359	R 2273 843	R 2393 755	+ 29.5%
Profit per hectare	**R 13 800**	**R 14 824**	**R 15 876**	**R 16 969**	**R 17 864**	**+ 29.4%**
Profit per cow	**R 3 067**	**R 3 425**	**R 3 792**	**R 4 165**	**R 4 500**	**+ 46.7%**
Profit margin per litre	**R 0.50**	**R 0.57**	**R 0.65**	**R 0.72**	**R 0.80**	**+ 58.8%**
Cost of production per litre	**R 4.10**	**R 4.03**	**R 3.95**	**R 3.88**	**R 3.80**	**−7.2%**
Operating profit margin	10.2%	11.6%	13.1%	14.6%	16.1%	+ 57.8%

6. Sensitivity analysis

To further analyse the impacts of a change to the percentage of pasture in the diet, a sensitivity analysis was completed for the three most significant factors that affect business performance and cause volatility in annual performance. These three factors are: (i) milk price, (ii) concentrate price, and (iii) seasonal impact of climate.

In Table 9 are the range of values for these factors, with each factor sensitised independently. Milk price was increased and decreased by R0.30 ($US0.02) and R0.60 ($US0.04) per litre. Concentrate price was increased and decreased by R200 ($US13.33) and R400 ($US26.67) per tonne.

Sensitivity to seasonal impact of climate was analysed by varying three factors in combination. These were:

(i) Pasture harvest was increased and decreased by 0.5 and 1.0 t dry matter per hectare with all pasture costs held constant, effectively decreasing or increasing the cost of pasture per tonne dry matter. The increase or decrease in pasture harvest was offset with a decrease or increase in supplement consumption based on equal volumes of concentrate and maize silage.

(ii) Maize silage yield was increased and decreased by 0.5 and 1.0 t dry matter per hectare with all maize silage costs held constant, effectively decreasing or increasing the cost of maize silage per tonne dry matter. The increase or decrease in maize silage yield was offset with an increase or decrease in maize silage on hand at the end of the year, with changes in stock on hand valued at the cost of production.

(iii) Concentrate price was increased and decreased by R100 ($US6.67) and R200 ($US13.33) per tonne caused by two factors. First, with higher or lower levels of pasture in the diet, there would be a change in the requirement for supplemented protein, minerals and trace elements in the concentrate mix. Second, there would be an increase or decrease in demand for concentrates by dairy farmers. In combination, these factors would affect the price of concentrates.

The results of the sensitivity analysis for milk price are shown in Table 10, with the right-hand column outlining the difference between the model with 57% pasture in the cows' diet and the base year. The data in the first section of the table confirms that profit, represented by return on capital, increases in all scenarios as the percentage of pasture in the diet increases. The comparative impact is significantly greater at a lower milk price than a higher one. Comparing the results for the difference between the 57% model and the base year, profit (return on capital) increases 2.46% at the lowest milk price and 0.71% at the highest milk price.

The second section of Table 10 confirms that profit margin per litre increases in all scenarios as the percentage of pasture in the diet increases. The comparative impact is the same at all milk prices.

Table 9. Sensitivity analysis parameters.

SENSITIVITY TABLE	Units	−−	−	BASE	+	+ +
MILK PRICE Sensitivity						
Milk Price Change	**Rand / litre**	**−R 0.60**	**−R 0.30**		**+ R 0.30**	**+ R 0.60**
Milk Price	Rand / litre	R 4.00	R 4.30	**R 4.60**	R 4.90	R 5.20
CONCENTRATE PRICE Sensitivity						
Concentrate Change	**Rand / tonne**	**+ R 400**	**+ R 200**		**−R 200**	**−R 400**
Concentrate Price	Rand / tonne	R 4 200	R 4 000	**R 3 800**	R 3 600	R 3 400
SEASONAL IMPACT OF CLIMATE Sensitivity						
Pasture Harvest Change	**tDM / ha**	**−1.0**	**−0.5**		**+ 0.5**	**+ 1.0**
Pasture Harvest	tDM / ha	10.3	10.8	**11.3**	11.8	12.3
Maize Silage Change	**tDM / ha**	**−1.0**	**−0.5**		**+ 0.5**	**+ 1.0**
Maize silage Yield	tDM / ha	13.0	13.5	**14.0**	14.5	15.0
Maize Silage Cost	Rand / tDM	R 1 238	R 1 193	**R 1 150**	R 1 110	R 1 073
Concentrate Change	**Rand / tonne**	**+ R 200**	**+ R 100**		**−R 100**	**−R 200**
Concentrate Price	Rand / tonne	R 4 000	R 3 900	**R 3 800**	R 3 700	R 3 600

Table 10. Sensitivity analysis results for milk price.

Profit (Return on Capital)	Milk Price Change	Base Year 41% Pasture	Model #1 45% Pasture	Model #2 49% Pasture	Model #3 53% Pasture	Model #4 57% Pasture	Difference 57% to 41%
	−R 0.60/litre	0.53%	1.19%	1.83%	2.45%	2.99%	+ 2.46%
	−R 0.30/litre	3.27%	3.80%	4.33%	4.84%	5.29%	+ 2.02%
	Base	**6.01%**	**6.41%**	**6.82%**	**7.23%**	**7.59%**	**+ 1.58%**
	+ R 0.30/litre	8.75%	9.02%	9.31%	9.63%	9.89%	+ 1.14%
	+ R 0.60/litre	11.48%	11.63%	11.81%	12.02%	12.19%	+ 0.71%
Profit Margin per Litre (Rand)	**Milk Price Change**	**Base Year 41% Pasture**	**Model #1 45% Pasture**	**Model #2 49% Pasture**	**Model #3 53% Pasture**	**Model #4 57% Pasture**	**Difference 57% to 41%**
	−R 0.60/litre	-R 0.10	-R 0.03	R 0.05	R 0.12	R 0.20	+ R 0.30
	−R 0.30/litre	R 0.20	R 0.27	R 0.35	R 0.42	R 0.50	+ R 0.30
	Base	**R 0.50**	**R 0.57**	**R 0.65**	**R 0.72**	**R 0.80**	**+ R 0.30**
	+ R 0.30/litre	R 0.80	R 0.87	R 0.95	R 1.02	R 1.10	+ R 0.30
	+ R 0.60/litre	R 1.10	R 1.17	R 1.25	R 1.32	R 1.40	+ R 0.30

Comparing the results for the difference between the 57% model and the base year, profit margin per litre increases R0.30 per litre.

The results of the sensitivity analysis for concentrate price are shown in Table 11, with the right-hand column outlining the difference between the model with 57% pasture in the cows' diet and the base year. The data in the first section of the table confirms that profit, represented by return on capital, increases in all scenarios as the percentage of pasture in the diet increases. However, the effect is greater at a higher concentrate price than a lower one. Comparing the results for the difference between the 57% model and the base year, profit (return on capital) increases 2.08% at the highest concentrate price and 1.08% at the lowest concentrate price.

The second section of Table 11 confirms that profit margin per litre increases in all scenarios as the percentage of pasture in the diet increases. The comparative effect is similar at all concentrate prices, though greater at a higher concentrate price. Comparing the difference between the 57% model and the base year, profit margin per litre increases R0.33 per litre at the highest concentrate price and R0.26 per litre at the lowest concentrate price.

Table 11. Sensitivity analysis results for concentrate price.

Profit (Return on Capital)	Concentrate Price Change	Base Year 41% Pasture	Model #1 45% Pasture	Model #2 49% Pasture	Model #3 53% Pasture	Model #4 57% Pasture	Difference 57% to 41%
	+ R 400/tonne	4.45%	4.99%	5.53%	6.06%	6.53%	+ 2.08%
	+ R 200/tonne	5.23%	5.70%	6.18%	6.65%	7.06%	+ 1.83%
	Base	**6.01%**	**6.41%**	**6.82%**	**7.23%**	**7.59%**	**+ 1.58%**
	−R 200/tonne	6.79%	7.12%	7.46%	7.82%	8.12%	+ 1.33%
	−R 400/tonne	7.57%	7.83%	8.11%	8.40%	8.65%	+ 1.08%
Profit Margin per Litre (Rand)	**Concentrate Price Change**	**Base Year 41% Pasture**	**Model #1 45% Pasture**	**Model #2 49% Pasture**	**Model #3 53% Pasture**	**Model #4 57% Pasture**	**Difference 57% to 41%**
	+ R 400/tonne	R 0.33	R 0.41	R 0.49	R 0.58	R 0.66	+ R 0.33
	+ R 200/tonne	R 0.42	R 0.49	R 0.57	R 0.65	R 0.73	+ R 0.31
	Base	**R 0.50**	**R 0.57**	**R 0.65**	**R 0.72**	**R 0.80**	**+ R 0.30**
	−R 200/tonne	R 0.59	R 0.65	R 0.72	R 0.80	R 0.87	+ R 0.28
	−R 400/tonne	R 0.67	R 0.74	R 0.80	R 0.87	R 0.94	+ R 0.26
Cost of Production per Litre (Rand)	**Concentrate Price Change**	**Base Year 41% Pasture**	**Model #1 45% Pasture**	**Model #2 49% Pasture**	**Model #3 53% Pasture**	**Model #4 57% Pasture**	**Difference 57% to 41%**
	+ R 400/tonne	R 4.27	R 4.19	R 4.11	R 4.02	R 3.94	−R 0.33
	+ R 200/tonne	R 4.18	R 4.11	R 4.03	R 3.95	R 3.87	−R 0.31
	Base	**R 4.10**	**R 4.03**	**R 3.95**	**R 3.88**	**R 3.80**	**−R 0.30**
	−R 200/tonne	R 4.01	R 3.95	R 3.88	R 3.80	R 3.73	−R 0.28
	−R 400/tonne	R 3.93	R 3.86	R 3.80	R 3.73	R 3.66	−R 0.26

The data in the third section of Table 11 confirms that cost of production per litre decreases in all scenarios as the percentage of pasture in the diet increases. The effect is similar at all concentrate prices, though more at a higher concentrate price. Comparing the results for the difference between the 57% model and the base year, cost of production per litre decreases R0.33 per litre at the highest concentrate price and R0.26 per litre at the lowest concentrate price.

Results of the sensitivity analysis for seasonal impact of weather conditions are in Table 12, with the right-hand column outlining the difference between the model with 57% pasture in the cows' diet and the base year. The data in the first section of the table confirms that profit, represented by return on capital, increases in all scenarios as the percentage of pasture in the diet increases. However, the effect of the change in seasonal conditions is greater with adverse conditions as compared to favourable conditions. Comparing the results for the difference between the 57% model and the base year, profit (return on capital) increases 1.80% in adverse climatic conditions and 1.35% in favourable conditions.

The data in the second section of Table 12 confirms that profit margin per litre increases in all scenarios as the percentage of pasture in the diet increases. The comparative impact is similar in all weather conditions, although it is marginally greater in favourable conditions. Comparing the results for the difference between the 57% model and the base year, profit margin per litre increases R0.28 per litre in adverse climatic conditions and R0.31 per litre in favourable conditions.

The data in the third section of Table 12 confirms that cost of production per litre decreases in all scenarios as the percentage of pasture in the diet increases. The effect is similar in all climatic conditions, and marginally greater in favourable conditions. Comparing the results for the difference between the 57% model and the base year, cost of production per litre decreases R0.28 per litre in adverse climatic conditions and R0.31 per litre in favourable conditions.

Sensitivity analysis relating to adverse climatic conditions showed that farms which include a higher percentage of pasture in the diet are more economically resilient, including during drought. This appears counter intuitive. This outcome is because any individual farm, including the one modelled, is equally exposed to the same reduction in pasture availability in adverse climatic conditions regardless of the production system that is implemented, given each farm will have a predetermined area of irrigated and dryland pasture. However, farms that have higher stocking rates and a lower percentage of pasture in the diet will have a higher total demand for supplements in

Table 12. Sensitivity analysis results for seasonal impact of climate.

Profit (Return on Capital)	Pasture Harvest Change	Base Year 41% Pasture	Model #1 45% Pasture	Model #2 49% Pasture	Model #3 53% Pasture	Model #4 57% Pasture	Difference 57% to 41%
	−1.0/tDM	3.75%	4.21%	4.68%	5.15%	5.55%	+ 1.80%
	−0.5/tDM	4.89%	5.32%	5.76%	6.20%	6.58%	+ 1.69%
	Base	**6.01%**	**6.41%**	**6.82%**	**7.23%**	**7.59%**	**+ 1.58%**
	+ 0.5/tDM	7.11%	7.48%	7.86%	8.25%	8.58%	+ 1.47%
	+ 1.0/tDM	8.20%	8.54%	8.89%	9.25%	9.55%	+ 1.35%
Profit Margin per Litre (Rand)	**Pasture Harvest Change**	**Base Year 41% Pasture**	**Model #1 45% Pasture**	**Model #2 49% Pasture**	**Model #3 53% Pasture**	**Model #4 57% Pasture**	**Difference 57% to 41%**
	−1.0/tDM	R 0.26	R 0.32	R 0.39	R 0.46	R 0.53	+ R 0.28
	−0.5/tDM	R 0.38	R 0.45	R 0.52	R 0.59	R 0.67	+ R 0.29
	Base	**R 0.50**	**R 0.57**	**R 0.65**	**R 0.72**	**R 0.80**	**+ R 0.30**
	+ 0.5/tDM	R 0.62	R 0.70	R 0.77	R 0.85	R 0.93	+ R 0.30
	+ 1.0/tDM	R 0.74	R 0.82	R 0.90	R 0.98	R 1.05	+ R 0.31
Cost of Production per Litre (Rand)	**Pasture Harvest Change**	**Base Year 41% Pasture**	**Model #1 45% Pasture**	**Model #2 49% Pasture**	**Model #3 53% Pasture**	**Model #4 57% Pasture**	**Difference 57% to 41%**
	−1.0/tDM	R 4.35	R 4.28	R 4.21	R 4.14	R 4.07	−R 0.28
	−0.5/tDM	R 4.22	R 4.15	R 4.08	R 4.01	R 3.93	−R 0.29
	Base	**R 4.10**	**R 4.03**	**R 3.95**	**R 3.88**	**R 3.80**	**−R 0.30**
	+ 0.5/tDM	R 3.98	R 3.90	R 3.83	R 3.75	R 3.67	−R 0.30
	+ 1.0/tDM	R 3.86	R 3.78	R 3.71	R 3.62	R 3.55	−R 0.31

a drought because of the higher number of cows per hectare and will be adding additional supplements, and likely higher cost supplements, to a business that is already carrying a higher cost of feed per cow and a higher cost of production per litre. With supplements having a greater cost per tonne dry matter than pasture (see Table 2), farms using production systems with a lower percentage of pasture in the diet and a higher percentage of supplement in the diet carry a higher level of risk economically in a drought.

In summary, the sensitivity analysis confirms that overall business performance under a range of conditions improves as the percentage of pasture in the cows' diet increases. This conclusion held under all circumstances that were analysed. Profit increased more significantly when business conditions were unfavourable as opposed to when they were favourable, for example, when milk price was lower, concentrate price was higher, or climatic conditions less favourable. Profit margin per litre and cost of production per litre improved in a uniform way across all circumstances that were analysed.

7. Discussion

South African dairy farms risk losing their international competitive advantage in profit and cost of production because of their comparatively high feed cost per litre, especially if their labour and other non-feed costs increase over time to the levels of other southern hemisphere pasture-based countries.

The impacts of changes in production systems, as outlined in this paper, demonstrate a potential opportunity for dairy farmers to reduce costs of production, increase margins on output, and increase whole farm profit. Reducing cost of production and increasing profit margin per litre provide an opportunity to increase the ability of dairy businesses to withstand increasing volatility in milk price, concentrate price, climate, or other factors.

These opportunities would appear to be equally relevant to farmers in several other countries that have followed a similar pathway to farmers in South Africa and substantially increased the proportion of supplement and decreased the percentage of pasture in the cows' diet. Australia, Argentina, Uruguay, and United Kingdom are all examples of countries that have followed a similar pathway, although farmers in these other countries have not been able to increase pasture harvest to the extent achieved in South Africa, and they have experienced larger increases in costs of production.

A change to a farm production system is a decision of substantial magnitude. The difficulty for the farmer, and their advisor, is knowing what cost inputs and change in pasture harvest should be assumed when developing the whole farm assessment. The challenge for dairy farmers considering a change in their production systems that involves increasing the percentage of pasture in the diet of the herd is that both revenue and costs are likely to be less than the higher input system they may currently operate. The possible reduction in revenue can often be estimated with reasonable accuracy, but the details of the improvements in the cost structure is more difficult to ascertain before the change. The critical question is: will the reduction in costs reduce sufficiently to more than offset the reduction in receipts?

As outlined in this paper, the answer to this question can be "yes it will", though decisions of any magnitude by farmers about how they operate their business warrant assessing using the "whole farm approach", as explained by Malcolm, Makeham, and Wright (2005).

Another major challenge when considering a significant increase in pasture as a percentage of the diet is whether the existing cow genotype on the farm will function efficiently with the potential change in diet. As reported by Beca (2020a), the type (genotype) of cow that suits a diet mostly comprising pasture, and which needs to walk to and from paddocks once or twice a day as well as harvest the pasture in the paddock themselves, is quite different to the type of cow that suits being confined in a feedlot or on a feedpad and is provided all, or the majority, of the feed it requires without moving outside a pen or yard. These differences in genotype have been documented by Harris and Kolver (2001).

For many farms, implementing a substantial change in the production system by increasing the percentage of pasture in the diet by, say, more than 10% in absolute terms, could require a change in the genotype of cow. A significant change in cow genotype could take 5–10 years to implement, which might mean annual increases of around 2%–3% of pasture in the diet would be a realistic rate of change.

However, the potential improvements in cost of production, profit margin per litre, and profit from increasing pasture as a percentage of the diet are substantial. The impact of this potential reduction in cost structure is that the South African pasture-based dairy industry could significantly close the gap between its present performance and the best performed country, New Zealand, while increasing South Africa's advantage compared to all the other countries. This change may well ensure that the South African dairy industry remains in a strong, internationally competitive position should the labour and other non-feed costs substantially increase from their present levels in the future.

Although this paper outlines a potential method and the inputs for a South African pasture-based dairy farm analysis, and potentially for an Australian dairy farm analysis, further research would be recommended to identify with more confidence the impact of changes to the percentage of pasture in the cows' diet on dairy farm performance. It would also be recommended that leading industry organisations develop extension projects that provide farmers and their advisors with the knowledge and skills to complete a whole of farm assessment on which to base this decision, as well as the skills to develop an implementation plan that would most probably need to cover multiple years.

8. Conclusion

Over the past decade, on average, dairy farmers in the South African pasture-based dairy industry have produced high profits as defined by return on capital relative to the profits of dairy farmers in New Zealand, Australia, United States, Argentina, Uruguay, Ireland, and United Kingdom. This high level of profit has been based on a high pasture harvest and stocking rate per hectare, moderate to low profit per cow, and a relatively low value of assets employed.

On average, South African dairy farmers are competitive with other countries in performance measures such as total revenue per litre and have markedly lower labour and other non-feed costs per litre of milk produced. Feed cost per litre is relatively high compared to farmers in other pasture-based countries, despite South African farmers having the second highest level of pasture harvested per hectare after New Zealand.

The cost of feed is determined by the cost of each of the three components (pasture, concentrate, and non-pasture forage) and the relative proportions of each of these three components in the total diet. Dairy farmers in South Africa have moderate to low average costs for each of the three components of the diet of their herds, and little opportunity to further lower the costs of each component. Changing the relative proportions of each feed in the total supply of feed is the only realistic option for reducing the average cost of the total feed supply. Using less of the relatively high-cost supplementary feedstuffs and using more of the relatively cheaper pasture is the imperative.

If a typical South African dairy farmer in 2019/2020 whose feeding system was based on pasture and having 41% of pasture in the cows' diet increased the percentage of pasture to 57%, this would reduce cost of production per litre by R0.30 or $US0.02 (−7%), increase profit margin per litre by R0.30 or $US0.02 (+59%), increase profit per cow by R1 433 or $US96 (+47%), and increase profit as defined by return on capital by 1.58% (+26%).

These improvements in the annual performance of the typical pasture-based dairy farm would make the farm business more economically resilient over time: it will be better equipped to cope with volatility in milk price, wide-ranging seasonal conditions, varying supplement prices, rising costs, and all the other factors that challenge dairy farming. If more farmers in the dairy industry relied more on growing and harvesting pasture and less on buying in supplementary feeds, the international competitiveness of South African dairy production would increase.

Notes

1. At the forefront of this group was an individual farmer, Trevor Elliott of Grasslands Agriculture, who was farming in Tsitsikamma, Eastern Cape.
2. Pasture harvest is the equivalent tonnage of standardised (10.5 MJ ME/kgDM) energy density pasture consumed per hectare. Any pasture hay and silage conserved on the dairy farm is included in the total pasture yield. This is a back-calculation based on inputs and outputs.

Acknowledgements

Bill Malcolm of University of Melbourne helped with reviewing and editing this paper. Mark Neal of DairyNZ worked on some of the statistical analysis presented in this paper and provided insights into methods and interpretation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Consent for publication

Written informed consent for publication of his details was obtained from Trevor Elliott of Grasslands Agriculture, Tsitsikamma, Eastern Cape.

References

Beca, D. 2020a. Evaluating the loss of profitability and declining milk production in the Australian dairy industry. *Australasian Agribusiness Perspectives* 23, no. 9: 136–64.

Beca, D. 2020b. Key determinants of profit for pasture-based dairy farms. *Australasian Agribusiness Perspectives* 23, no. 16: 247–74.

Beca, D. 2020c. *Addendum to Key determinants of profit for pasture-based dairy farms – South Africa versus Australia*. Melbourne: Red Sky Agricultural Pty Ltd. http://redskyagri.com/page/redsky_61.html.

Beca, D. 2021a. International Dairy Industry Farm Performance Report: Australia vs New Zealand vs United States vs Argentina vs Uruguay vs South Africa vs Ireland vs United Kingdom. Melbourne: Red Sky Agricultural Pty Ltd. URL http://redskyagri.com/page/redsky_58.html.

Beca, D. 2021b. Changing Production Systems: Improving Profit in Australian Dairy. In *Proceedings of the 2021 Grasslands Society of Southern Australia Conference*, Online, Australia, 13–21.

Beca, D. 2021c. Labour cost and labour efficiency within the Australian dairy industry. *Australasian Agribusiness Perspectives* 24, no. 18: 258–81.

Chapman, D.F., D. Beca, J. Hill, J. Tharmaraj, J.L. Jacobs, and B.R. Cullen. 2014. Increasing home-grown forage consumption and profit in non-irrigated dairy systems. 4. economic performance. *Animal Production Science* 54: 256–62.

Dillon, P., J.R. Roche, L. Shalloo, and B. Horan. 2005. Optimising financial returns from grazing in temperate pastures. In *Utilisation of Grazed Grass in Temperate Animal Systems*, Proceedings Satellite Workshop, 20th International Grasslands Congress, Cork, Ireland, 131–147.

Hanson, G.D., S. Cunningham, A. Ford, L.D. Muller, and R.L. Parsons. 1998. Increasing intensity of pasture use with dairy cattle: An economic analysis. *Journal of Production Agriculture* 11: 175–9.

Harris, B.L., and E.S. Kolver. 2001. A review of holsteinization on intensive pastoral dairy farming in New Zealand. *Journal of Dairy Science* 84: E56–E61.

Hemme, T., M.M. Uddin, and O.A. Ndambi. 2014. Benchmarking cost of production in 46 countries. *Journal of Reviews on Global Economics* 3: 254–70.

Kriegl, T. 2001. *Wisconsin grazing dairy profitability analysis – A preliminary five-year comparison of the cost of production of selected "conventional" and grazing Wisconsin dairy farms*. City: University of Wisconsin Centre for Dairy Profitability.

Macdonald, K.A., J.W. Penno, J.A.S. Lancaster, A.M. Bryant, J.M. Kidd, and J.R. Roche. 2017. Production and economic responses to intensification of pasture-based dairy production systems. *Journal of Dairy Science* 100: 6602–19.

Malcolm, Bill, Jack Makeham, and Vic Wright. 2005. *The farming game, agricultural management and marketing*. Melbourne: Cambridge University Press.

Core Team, R. 2013. *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. https://www.r-project.org/.

Ramsbottom, G., B. Horan, D.P. Berry, and J.R. Roche. 2015. Factors associated with the financial performance of spring-calving, pasture-based dairy farms. *Journal of Dairy Science* 98: 3526–40.

Sources of data

AACREA (Asociación Argentina de Consorcios Regionales de Experimentación Agrícola) http://www.crea.org.ar/; producer-owned organisation in Argentina that has as its main purpose to help producers improve the economic and financial results of their farm business. AACREA has the largest dataset of dairy farm performance in Argentina.
AHDB (Agriculture and Horticulture Development Board, United Kingdom) http://www.ahdb.org.uk/.
CSO (Central Statistics Office, Ireland) http://www.cso.ie/.
DA (Dairy Australia) https://www.dairyaustralia.com.au/
DFMP (Dairy Farm Monitor Project, Australia) https://www.dairyaustralia.com.au/industry-statistics/dairy-farm-monitor-project.
DairyBase (New Zealand) http://www.dairynz.co.nz/business/dairybase.
DairyNZ http://www.dairynz.co.nz/.
DEFRA (Department for Environment, Food and Rural Affairs, United Kingdom) http://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs.
FUCREA (Federación Uruguaya de Grupos CREA) http://www.fucrea.org/; producer-owned organisation in Uruguay that has as its main purpose to help producers improve the economic and financial results of their farm business. FUCREA has the largest dataset of dairy farm performance in Uruguay.
Genske Mulder (United States) http://www.genskemulder.com/: the largest dairy farm accountancy practice in United States. Genske Mulder produce benchmark data for dairies in Arizona, California, Colorado, Idaho, New Mexico, Texas, and Washington and in the regions of the Upper Midwest and Lower Midwest.
INALE (Instituto Nacional de la Leche) http://www.inale.org/: the Uruguayan National Milk Institute is a non-state public entity with its main task being to advise the government on dairy policy. The aim is to contribute to a joint public-private partnership aimed at the development of the Uruguayan dairy industry.
MAGYP (Ministerio de Agricultura, Ganadería y Pesca) http://www.argentina.gob.ar/agricultura-ganaderia-y-pesca: the Argentinian government's Ministry of Agriculture, Livestock and Fishing.
QDAS (Queensland Dairy Accounting Scheme); benchmarking analysis undertaken by Queensland Department of Agriculture and Fisheries http://www.daf.qld.gov.au/ with funding from Dairy Australia.
Red Sky Agricultural ('Red Sky') http://www.redskyagri.com/; commercial provider of farm business analysis and benchmarking software that primarily operates in Australia, New Zealand, and South Africa. Red Sky's major shareholder is the author of this paper.
Teagasc (Agricultural and Food Development Authority, Ireland) http://www.teagasc.ie/.
USDA (United States Department of Agriculture) http://www.usda.gov/.

Appendix

1. Definitions

Energy Corrected Milk (ECM): determines the amount of energy in the milk based upon milk, fat and protein and adjusted to 4.0% fat and 3.3% protein. ECM formula = milk production x ((0.383 x fat% + 0.242 x protein% + 0.7832) / 3.1138). Converting all milk ratios to energy corrected milk is required due to the otherwise confounding impact of the wide range in fat and protein per cent as a result of differing cow types, diets and production systems. This formula is used by the Dairy International Farm Comparison Network, as outlined in the following:
https://dairymarkets.org/PubPod/Reference/Library/Energy%20Corrected%20Milk.
Milksolids: refers to the combined weight of fat plus protein in the milk. These are the two saleable components that primarily impact on the price paid for milk. Utilising solids rather than litres (if not energy corrected) to determine the growth rate in milk production for each region eliminates the confounding impact of changes in fat and protein percentages in each country over time.

Table A1. Definitions of operating revenue and expenses utilised in calculation of operating profit.

Operating profit calculation	Definitions
Operating revenue	Milk sales + Livestock revenue[1] + Other non-milk revenue
[1] Livestock revenue	Livestock sales – livestock purchases + (closing numbers – opening numbers) x closing value per head
Operating expenses	Administration fees & overheads[2] + Animal health + Breeding & herd testing + Dairy shed expenses + Depreciation[3] + Electricity + Fertiliser + Freight + Irrigation + Pasture maintenance & renovation + Repairs & maintenance + Total supplement expenses[4] + Vehicle expenses + Management & labour expenses[5]
[2] Administration fees & overheads	Includes all office expenses plus professional fees plus rates, licences, levies and insurance
[3] Depreciation	Based on straight line depreciation over economic life of asset
[4] Total supplement expenses	Includes all concentrate and forage expenses (excluding pasture grown on dairy farm) fed to cows and growing heifers plus green feed crops grazed in-situ plus all expenses for grazing/support area utilised for cows and growing heifers as well as supplement production
[5] Management & labour expenses	Includes all direct labour expenses plus market salary value of any management provided by owner/family plus market hourly rate value of any labour provided by owner/family
Operating profit	Operating revenue – Operating expenses

Table A2. Calculations and definitions of ratios referenced in this paper.

Ratios	Calculation / Definition
Concentrate cost per tonne dry matter ("Consumed")	Consumed concentrate cost divided by tonne of dry matter consumed. Consumed concentrate cost includes the full purchase or production cost plus any storage cost prior to feeding to livestock, with wastage apportioned within this cost of feed.
Core per cow cost	[100% x (Animal health + Breeding & herd testing + Dairy shed expenses + Electricity + Freight + Grazing/Support area expenses + Industry levies) + 70% x Vehicle expenses + 50% x (Depreciation + Repairs & maintenance)] divided by total cows in herd.
Core per hectare cost per tonne dry matter of pasture harvest	[100% x (Administration fees & overheads excl. industry levies + Fertiliser excl. nitrogen + Green feed crops grazed in situ + Pasture maintenance & renovation) + 30% x Vehicle expenses + 50% x (Depreciation + Repairs & maintenance)] divided by effective dairy hectares divided by tonne of dry matter harvested per hectare.
Cost of production per litre or per kg milksolids	(Operating expenses minus livestock revenue minus other non-milk revenue) divided by total litres or total milksolids (ECM) produced.
Farm size (cow numbers)	Total number of cows in herd (milking plus dry cows).
Farm size (hectares)	Effective dairy farm area that is grazed by the cows.
Forage cost per tonne dry matter ("Consumed")	Consumed forage cost divided by tonne of dry matter consumed. Consumed forage cost includes the full purchase or production cost plus any storage cost prior to feeding to livestock, with wastage apportioned within this cost of feed.
Labour cost per cow	Management & staff costs incl. imputed labour costs divided by total cows in herd.
Labour efficiency – cows per full-time staff equivalent	Total cows in herd divided by number of 50-hour full-time staff equivalents.
Milk price	Milk price per litre or per kg milksolids (ECM).
Milk production per cow	Total litres (ECM) produced divided by total cows in herd.
Milk production per hectare	Total litres (ECM) produced divided by effective dairy hectares.
Operating profit margin	Operating profit divided by operating revenue.
Pasture as per cent of diet	Percent of energy provided from pasture harvested on the effective dairy area as a percentage of total annual energy requirements of the cows.
Pasture cost per tonne dry matter ("Consumed")	Direct pasture cost divided by tonne of dry matter harvested. Direct pasture cost includes pasture maintenance and renovation (including green feed crops grazed in situ), fertiliser (including nitrogen), all pasture irrigation costs, and the direct silage and hay costs for pasture conserved on the dairy farm.
Pasture harvest	This is the equivalent tonnage of standardised (10.5–11.0 MJ ME/kgDM) energy density pasture consumed per hectare. Any hay and silage conserved on the dairy farm is included in the total pasture yield. This is a back-calculation based on inputs and outputs.
Profit per cow	Operating profit divided by total cows in herd (milking plus dry cows).
Profit per hectare	Operating profit divided by effective dairy hectares (grazed by the cows).
Profit margin per litre or per kg milksolids	Operating profit divided by total litres or total milksolids (ECM) produced.
Return on (total) capital	Operating profit divided by the total value of all assets employed in the business (regardless of ownership/financing structure). Changes in asset values, including appreciation of land values, are not included in this calculation.
Stocking rate	Total cows in herd divided by effective dairy hectares.
Supplement cost per litre or per kg milksolids	(Concentrates + Forages + Grazing/Support area expenses) divided by total litres or total milksolids (ECM) produced.
Total consumed per cow (tDM/cow/year)	Total tonnes of dry matter consumed per cow in herd per year, where the energy supplied from pasture is standardised at 10.5–11.0 MJ ME/kg DM, the energy supplied from forages is standardised at 9.5 MJ ME/kg DM, and the energy supplied from concentrates is standardised at 12.5 MJ ME/kg DM.
Total expenses per litre or per kg milksolids	Operating expenses divided by total litres or total milksolids (ECM) produced.
Total feed cost per litre or per kg milksolids	(Concentrates + Forages + Grazing/Support area expenses + Green feed crops grazed in-situ + Fertiliser incl. nitrogen + Irrigation + Pasture maintenance & renovation) divided by total litres or total milksolids (ECM) produced.